

The ATLAS Forward Physics Program

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On behalf of the ATLAS experiment

We describe the ATLAS Forward Physics Program at low luminosity using the rapidity gap method and a dedicated detector called ALFA to tag the protons. We also describe the physics topics of the ATLAS Forward Physics Project at high instantaneous luminosity.

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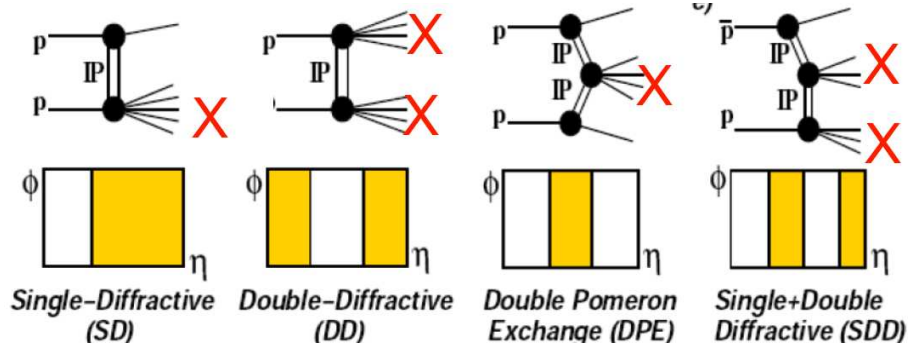


Figure 1: Scheme of diffractive events.

1. ATLAS Forward Physics Program

The ATLAS Forward Physics Program benefits from the good coverage of the ATLAS detector in the forward region [1]. In particular, we can quote the Luminosity Cerenkov Integrating Detector (LUCID) at 17 m from the ATLAS nominal interaction point, the Zero Degree Calorimeter (ZDC) at 140 m and the Absolute Luminosity for ATLAS (ALFA) roman pots at 240 m. In addition, the ATLAS Forward Physics Project (AFP) under discussion within ATLAS foresees to install additional forward detectors (movable beam pipes) at 220 and 420 m from the ATLAS interaction point.

The first diffractive measurements which can be performed in ATLAS are given in Fig. 1. At low luminosity, it is possible to select diffractive events using the forward rapidity gap method. Since there is no colour exchange between the intact proton in the final state and the object produced in the central region (pions, jets, photon...), a rapidity gap devoid of any activity is present in the forward region. The ATLAS forward detectors and their good coverage in the forward region (the Forward Calorimeter FCAL $3.2 < |\eta| < 4.9$, LUCID $5.6 < |\eta| < 6.0$ and ZDC $|\eta| > 8.3$) allow to measure single diffraction and double pomeron exchanges. The central gaps can be measured using the hadronic calorimeter $|\eta| < 3.2$ and the inner detectors ($|\eta| < 2.5$). More complicated events such as the last one of Fig. 1 can also be measured.

In the next sections, we will cover the potential measurements from ATLAS using the rapidity gap method, the ALFA roman pots at low luminosity and the AFP movable beam pipes at high luminosity.

2. Early diffractive measurements in ATLAS

2.1 Hard single diffraction and double pomeron exchanges

One of the first possible measurements is to look for single diffractive events where jets, W s or Z s are produced in the central detector using the rapidity gap method. The soft survival probability can be determined using the first data while comparing the data with or without a gap in the forward region. The first diffractive measurements can be performed with a limited luminosity. As an example, approximately 5000 (8000) single diffractive dijet events can be produced in 100 pb^{-1}

with a jet transverse momentum above 20 (40) GeV after taking into account the trigger prescale at low luminosity.

Requesting two central jets in the central ATLAS detector and the presence of a rapidity gap in each proton direction will allow to select Double Pomeron Exchange events. As performed by the CDF collaboration at the Tevatron [2], it is possible to measure the dijet mass fraction as an example, which allows to distinguish between exclusive and inclusive diffractive events. The dijet mass fraction is defined as the ratio of the dijet mass and the total mass in the event (measured for instance in the ATLAS calorimeter). For exclusive events, the dijet mass fraction is close to 1 since only two jets and the two scattered protons and nothing else are produced in this kind of events. For inclusive events, part of the energy is lost in pomeron remnants and the dijet mass ratio will be significantly smaller than 1. A such measurement allows to measure the exclusive diffractive dijet production cross section and it will be useful to constrain further the exclusive models and give better prediction on diffractive exclusive Higgs boson production cross section in particular [3].

2.2 Photon induced processes

Two kinds of photon induced processes are specially interesting, namely the exclusive dilepton production and the photoproduction processes. In exclusive dilepton production $pp \rightarrow p\ell\ell p$, two protons and two leptons originating from QED processes are produced in the final state. To select such events, one can require the presence of one rapidity gap on each proton side, two isolated back-to-back leptons, the presence of an exclusive vertex (no other track is present than those originating from the leptons). The typical cross section is 10 pb for lepton p_T above 10 GeV.

The photoproduction processes can produce J/Ψ or Υ resonances originating from photon-pomeron exchanges. The cross section is also of the order of 10 pb and the processes can be detected via the lepton decays of J/Ψ or Υ . These events are particularly interesting to constrain further the unintegrated gluon distributions which are one of the inputs to compute diffractive exclusive cross sections, for instance for Higgs production [4].

2.3 Jet gap jet events

The other process of interest which can be studied using the first ATLAS data is the jet gap jet event. To select such processes, one requires the presence of two jets reconstructed in the ATLAS calorimeter and a rapidity gap devoid of any activity between them. These processes allow a direct test of the Balitsky Fadin Kuraev Lipatov [5] (BFKL) resummation and recently, the Next-to-Leading Logarithm (NLL) BFKL equation was implemented for these processes in HERWIG [6]. It leads to a fair description of the CDF and D0 data.

3. Diffractive measurements using ALFA

The main motivation of installing the ALFA detectors is the total cross section measurement. This detector was described in another contribution at this conference [1]. The idea is to measure the elastic cross section in the Coulomb and interference region (see Fig. 3), which can be used to have an absolute measurement of the luminosity. The elastic cross section is the sum of the

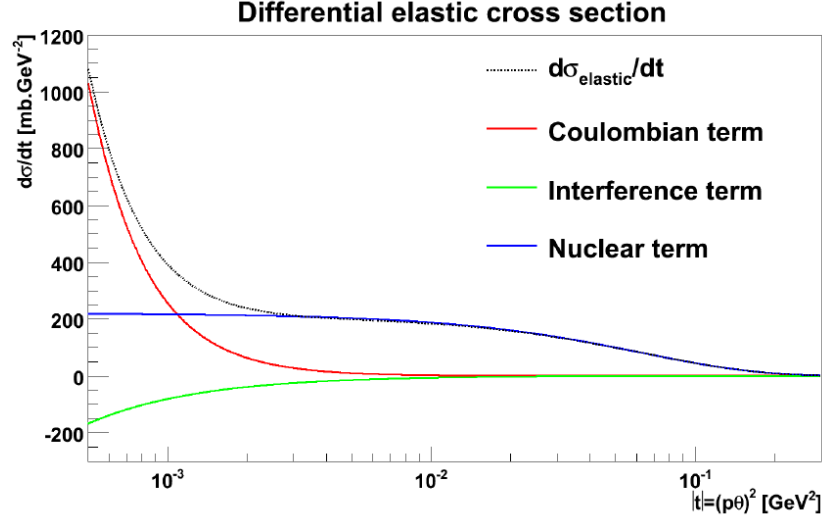


Figure 2: Coulombian, nuclear and interference terms in the elastic cross section.

coulombian, nuclear and interference terms

$$\frac{dN}{dt} = L \left(\frac{4\pi\alpha^2 G^4(t)}{|t|^2} - \frac{\alpha\rho\sigma_{tot}G^2(t)e^{-B|t|/2}}{|t|} + \frac{\sigma_{tot}^2(1+\rho)^2 e^{-B|t|}}{16\pi} \right). \quad (3.1)$$

The luminosity L , the total cross section, and the B and ρ parameters appearing in the elastic cross section formula are determined by fitting the dN/dt spectrum in the interference and nuclear regions [7]. The measurement requires the possibility to detect the protons in the final state down to $t \sim 3.7 \cdot 10^{-4} \text{ GeV}^2$ which means a proton angle down to $3 \mu\text{rad}$, which requires special high β^* runs at low luminosity. The total uncertainties on the elastic cross section measurement are expected to be less than 3% (beam properties: 1.2%, detector properties: 1.4%, background subtraction: 1.1%, 1.8% statistical error for 100 hours of measurement at low luminosity).

The ALFA detector also allows to measure soft single diffractive events in dedicated runs where ALFA will be used to measure elastic events. It is possible to measure forward protons in the region: $6.3 < E_{proton} < 7 \text{ TeV}$, and single diffractive measurements are possible for $\xi < 0.01$ and non-diffractive proton measurements for $0.01 < \xi < 0.1$. 1.5 million events are expected in 100 hours at $10^{27} \text{ cm}^{-2}\text{s}^{-1}$.

4. Diffractive measurements at high luminosity

The AFP project under discussion in the ATLAS collaboration will allow to detect protons in the final state using additional proton taggers to be intalled at 220 and 420 meters from the ATLAS nominal interaction point. The movable beam pipes will host 3D Silicon detectors allowing to measure the position of the scattered protons with a precision better than $10 \mu\text{m}$ and time of flight detectors (GASTOF and QUARTIC) to measure the arrival time of the protons with a precision of 5-10 ps [1].

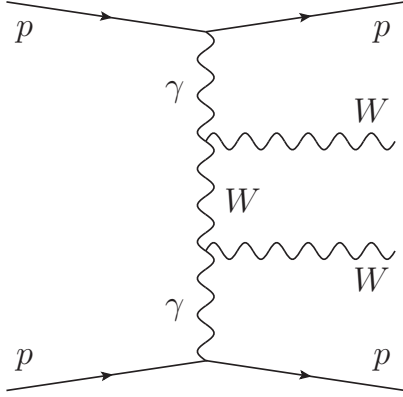


Figure 3: Sketch diagram showing the two-photon production of a central system.

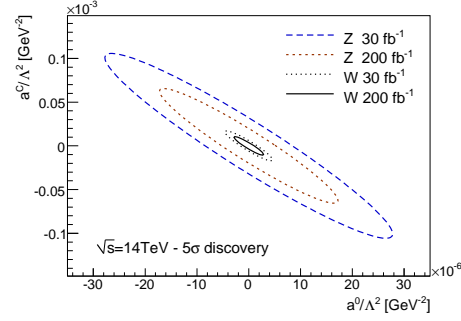


Figure 4: 5σ discovery contours for all the WW and ZZ quartic couplings at $\sqrt{s} = 14$ TeV for a luminosity of 30 fb^{-1} and 200 fb^{-1} .

In addition to QCD studies of diffractive events and a better understanding of the pomeron structure, the main motivations of AFP are the exclusive diffractive Higgs production and the study of γW and γZ anomalous couplings. The exclusive Higgs production cross section and signal-over-background at the LHC was studied in great details [8] after a full simulation of signal and background events in the ATLAS detectors. As an example, the significance is larger than 3.5σ (resp. 5σ) for 60 fb^{-1} (resp. three years at the highest luminosity). Diffractive Higgs production is complementary to the standard non-diffractive search and allows a spin determination of the Higgs boson.

The study of W and Z pair production via photon exchanges ($pp \rightarrow pWWp$) allows to study in detail the quartic and triple gauge anomalous $W\gamma$ and $Z\gamma$ couplings which are predicted in particular by Higgsless and extradimension models. The present LEP limits on quartic anomalous couplings can be improved by up to four orders of magnitude by tagging the intact protons in the final state and the W and Z decays into leptons for instance in the ATLAS detector, which allows to reach the expected anomalous couplings for Higgsless models [9]. The tagging of the protons using the ATLAS Forward Physics detectors is the only method at present to test so small values of quartic anomalous couplings and thus to probe the Higgsless models in a clean way. In addition, photon-exchange processes allow to probe SUSY particle production and to assess their kinematical properties [9].

5. Conclusion

As a conclusion, we give in Table 1 the list of diffractive processes which can be measured in ATLAS as a function of luminosity. The future of diffractive measurements at the LHC is particularly rich and will especially benefit from the AFP project which will be at the interface of standard QCD measurements, beyond standard model searches and the search for the Higgs boson.

References

- [1] A. Brandt, these proceedings

Luminosity	Possible measurements
10 pb^{-1}	Jet gap jet (Mueller Navelet) Soft single diffraction total cross section (ALFA) Hard Single diffraction (jets, b jets...)
$10\text{-}100 \text{ pb}^{-1}$	Central exclusive production (jets) Single diffractive W/Z
$100\text{-}200 \text{ pb}^{-1}$	WW via photon exchange dilepton production CEP $\tau\tau$
30 fb^{-1}	Higgs (with AFP) Anomalous $W\gamma$ couplings (with AFP) Test of Higgsless / extradim models (with AFP)

Table 1: Possible diffractive measurements in ATLAS as a function of accumulated luminosity

- [2] CDF Collaboration, preprint hep-ex/0712.0604; O.Kepka, C. Royon, Phys. Rev.D**76** (2007) 034012.
- [3] C. Royon, R. Staszewski, these proceedings.
- [4] V.A. Khoze, A.D. Martin, M.G. Ryskin, Eur. Phys. J.C**55** (2008) 363.
- [5] L. N. Lipatov, Sov. J. Nucl. Phys. **23** (1976) 338; E. A. Kuraev, L. N. Lipatov and V. S. Fadin, Sov. Phys. JETP **45** (1977) 199; I. I. Balitsky and L. N. Lipatov, Sov. J. Nucl. Phys. **28** (1978) 822.
- [6] O. Kepka, C. Marquet, R. Peschanski and C. Royon, Phys. Lett. **B655** (2007) 236; Eur. Phys. J. C **55** (2008) 259.
- [7] ATLAS Coll., see <http://atlas-project-lumi-fphys.web.cern.ch/atlas-project-lumi-fphys/>; C. Royon, Proceedings of Science DIFF2006 (2006) 021; M. Heller, PhD thesis, unpublished.
- [8] V.A. Khoze, A.D. Martin, M.G. Ryskin, Eur. Phys. J. **C19** (2001) 477; Eur. Phys. J. **C23** (2002) 311; Eur. Phys. J. **C24** (2002) 581; M. Boonekamp, R. Peschanski, C. Royon, Phys. Rev. Lett. **87** (2001) 251806; Nucl. Phys. **B669** (2003) 277; B. Cox, F. Loebinger, A. Pilkington, JHEP 0710 (2007) 090; S. Heinemeyer et al., Eur. Phys. J. C **53** (2008) 231; M. Boonekamp, J. Cammin, S. Lavignac, R. Peschanski, C. Royon, Phys. Rev. **D73** (2006) 115011;
- [9] C.. Royon, these proceedings; E. Chapon, O. Kepka, C. Royon, Phys. Rev. **D81** (2010) 074003; O. Kepka and C. Royon, Phys. Rev. D **78** (2008) 073005 [arXiv:0808.0322 [hep-ph]]; J. de. Favereau et al., preprint arXiv:0908.2020; N. Schul, preprint arXiv:0910.0202 and these proceedings.